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Goddard Space Flight Center



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Low-Cost Thin-Layer Silicon Solar Cells

The problem:

The silicon solar cell is currently the most-well-known photovoltaic device utilized to convert solar energy to electric energy. The technology has advanced to the point where silicon solar panels used in spacecraft are capable of supplying several kilowatts of power to the craft instruments. Silicon solar cells, though, are still very costly to manufacture. Although production costs of single crystalline cells have dropped from \$100 to \$20 per peak watt, further cost reductions of one order of magnitude are required before they can be considered alternate energy sources.

The solution:

Two methods have been found to lower the cost of polycrystalline silicon solar cells. The first simplifies the manufacturing process directly; the second provides a means of bonding the silicon to differing substrates of less expensive material.

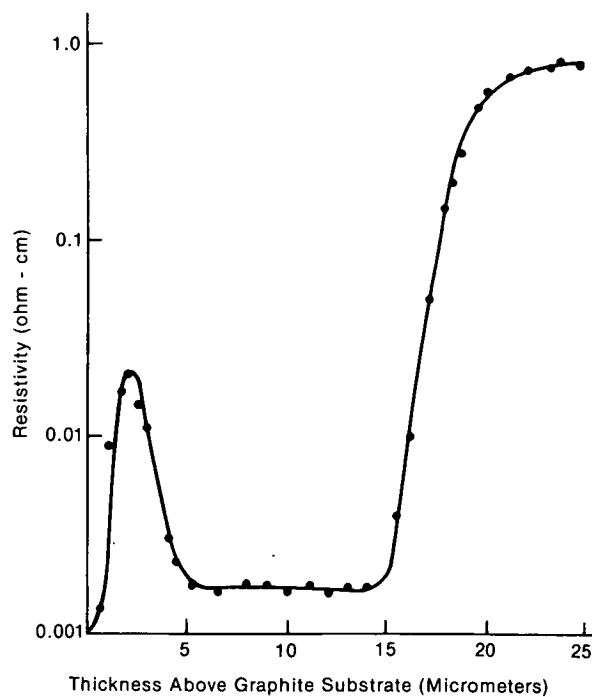
How it's done:

Successive layers of polycrystalline silicon containing appropriate dopants are deposited over supporting substrates of metallurgical-grade polycrystalline silicon, graphite, or steel. These materials are coated with a diffusion barrier of silica, borosilicate, or phosphosilicate to create a pn junction. When graphite is used as the substrate, a diffusion barrier of silicon carbide is formed between the graphite and the first overlying silicon layer. When steel is used, a diffusion barrier of silica, borosilicate, or phosphosilicate is deposited prior to the first polycrystalline layer in order to avoid the diffusion of contaminating iron atoms.

The pn junction must be very shallow. The n-layer (or upper layer) is 0.2 to 0.4 μm thick; the p-layer (or inner layer) is 10 to 100 μm thick. The junction is

prepared by: (1) thermally decomposing silane, (2) by the reduction of trichlorosilane or silicon tetrachloride with hydrogen at temperatures ranging from 900° to 1,200° C, or (3) by the thermal decomposition of dichlorosilane. Several such layers are deposited and appropriately doped to form the junction.

The figure shows the resistivity profile of the structured device (except for the n-layer which is obtained by the spreading resistance technique). The plot shows a high resistivity area in the silicon adjacent to the graphite-silicon interface and is apparently caused by the formation of silicon carbide.



Resistivity Profile of Polycrystalline Structure

(continued overleaf)

Fabricating the cell by decomposing polycrystalline silicon onto a steel substrate is complicated by several problems. One is the difference between thermal expansion coefficients of the materials. Silicon has an expansion coefficient of $4 \times 10^{-6}/^{\circ}\text{C}$, while most steels have coefficients of 14 to $16 \times 10^{-6}/^{\circ}\text{C}$. A diffusion barrier is used to minimize the difference in thermal expansion characteristics of the layers and is chemically inert to steel and silicon at high temperatures. Layers of films of silica, borosilicate, phosphosilicate, and aluminosilicate form suitable diffusion barriers between steel and silicon. Silica, borosilicate, and phosphosilicate are all inert toward silicon and steel at high temperatures and have the added advantage of being relatively soft. The thermal expansion coefficient of borosilicate also can be changed as a function of its composition.

The methods by which the silica and borosilicate diffusion barriers are deposited on the steel substrates are not critical. The thickness of the deposited diffusion barrier is 1 to 5 μm . Normally, the borosilicate diffusion layers contain from 10 to 18 percent boron, while phosphosilicate layers contain from 10 to 20 percent phosphorous. By using the above diffusion barrier materials, it is possible to prepare integral and tightly formed structures, such as silicon/silica/steel, silicon/borosilicate/steel, and silicon/silica-borosilicate/steel.

Suitable steels used for the substrates of the present cells include Armco silicon steel and USS Vitrenamel I. Prior to deposition of the first junction layer, the surface of the steel can be scavenged of oxygen by treating it with a reducing agent such as hydrogen at a temperature from 600° to $1,000^{\circ}\text{C}$.

Note:

Requests for further information may be directed to:

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Patent status:

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to:

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